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SUPPRESSION OF OCEAN CLUTTER IN HIGH FREQUENCY RADAR

Rafaat H. Khan
Centre for Cold Ocean Resources Engineering
Memorial University of Newfoundland
St. John's, Newfoundland, A1B 3X5

ABSTRACT

Strong ocean clutter levels restrict the target detection capabilities of high frequency (HF) radar. A recently proposed time-domain model for the ocean clutter may be used to selectively suppress the clutter component and enhance the target detection performance. The practical implementation of clutter suppression, based upon this model, involves tracking of multiple time-varying sinusoids; some techniques are discussed and initial results presented.

EXTENDED SUMMARY

HF radar has the unique potential for over-the-horizon detection of surface targets in the ocean environment. However, HF radar waves also interact very strongly with the ocean and the clutter level, over large ranges of Doppler frequencies, can easily mask the target signal. This ocean clutter spectrum has been extensively studied [1,2] and consists of two components. A narrowband component is due to electromagnetic scattering from ocean waves having wavelengths matched to half the radar wavelength; these waves are often referred to as 'Bragg' waves. The other broadband component is produced by second order effects from two sets of ocean waves. Maresca and Barnum [3] have investigated the feasibility of detecting ships with HF radar and concluded that the ocean clutter would limit target detection in significant portions of the Doppler spectrum. The resulting extent of target blind speeds would make such a radar device impractical.

In an attempt to develop a reliable technique for target detection, our initial investigation [4] was aimed towards understanding the time-domain characteristics of ocean clutter signals. Ongoing research has produced the following key result:

> The ocean clutter can be modelled as the sum of two independent angle modulated signals, centred about the Bragg Doppler frequencies.

In addition, a target signal, centred about its Doppler frequency, may be present. Multiple targets are generally not encountered if the radar range cell has small dimensions. Target detection thus involves detecting a third signal while tracking the two time-varying clutter signals about their known 'Bragg' Doppler frequencies.

We are presently investigating techniques to robustly track multiple sinusoids. One approach involves methods based on linear prediction to model the third order time varying data [5]. Good results have been obtained but this technique encounters difficulties when the target Doppler approaches one of the 'Bragg' frequencies. The problem lies in the fact that although the overall data can be easily modelled, decomposition into the individual components is only possible when the signals are well separated in frequency. When two of the

signals are close to each other in frequency, the estimated magnitudes annd phases of the signals are distorted with respect to the original signals. A diifferent approach [6] has been tried to isolate the individual signals by admaptively notching all the other signals. As shown in Fig. 1, such a scheme fofor three signals could be used to track two clutter and one target signal for a a single radar range cell. Problems were also reported, for this scheme, when two o signals were closely spaced. However for our application these problems can be ovovercome.

The ability of any structure to adapt to time varying signals dependds on the choice of error signals and the method of estimation for the various coefficient sensitivities required to update the variable coefficientss in the structure. In addition, parameters controlling the adaptation and convvergence rates must be matched to the characteristics of the input signal. Thene scheme of Fig. 1 has been implemented using biquadratic notch filters with lolow order adaptive tracking filters and initial results discussed below show thanat real-time target detection can be achieved.

A particular data set was chosen from a ship detection exxperiment where the ship Doppler was close to the Bragg Doppler frequency. Fig. 2a shows the spectrum of the radar data with the two clutter peaks as well as the ship target identified. It is noted that the sideband structure of one of thee 'Bragg' components overlaps that of the ship signal. Fig. 2b shows the reresult of estimating the time behaviour of these signals using the scheme of Fig. 1. The frequency overlap is clearly visible and the 'carrier' frequencies corrrespond to the peaks of the spectrum in Fig. 2a.

This technique has potential for the real-time suppression of oceann clutter for enhanced target detection. The resulting improvement in signal-to-noise ratio may contribute to establishing HF radar as an effective surveillancce device for over-the-horizon detection of surface targets.

References

[1] J. Walsh, "On the Theory of Electromagnetic Propagation Across a Rough Sea and Calculations in the VHF Region," Tech. Rep. prepared for Def. Res. Estab. Atlantic (DREA), Govt. of Canada, 1980.

[2] D.E. Barrick, "Remote sensing of sea state by radar," in Remote Sensing of the Troposphere, V.E. Derr, Ed., Washington, DC: GPO, pp. 12.1-12.45, 1972.

[3] J.W. Maresca Jr. and J.R. Barnum, "Theoretical limitation of the sensa on the detection of low doppler targets by over-the-horizon radar," IEEE Trarans. Ant. and Prop., vol. AP-30, pp. 837-844, 1982.

[4] R.H. Khan, B.J. Dawe and J. Walsh, "Time domain modelling of oceann clutter for ground wave radar," Proc. Can. Conf. on Electrical and Computeer Eng., Vancouver, B.C., pp. 715-718, 1988.

[5] D.K. Mitchell and R.H. Khan, "Target detection for HF radar," NECEC 90, St. John's, May 1990.

[6] T. Kwan and K. Martin, "Adaptive detection and enhancement of multiple sinusoids using a cascade IIR filter," in Proc. 1988 IEEE Int. Symp. Circuits Syst., Helsinki, Finland, pp. 2647-2650, June 1988.

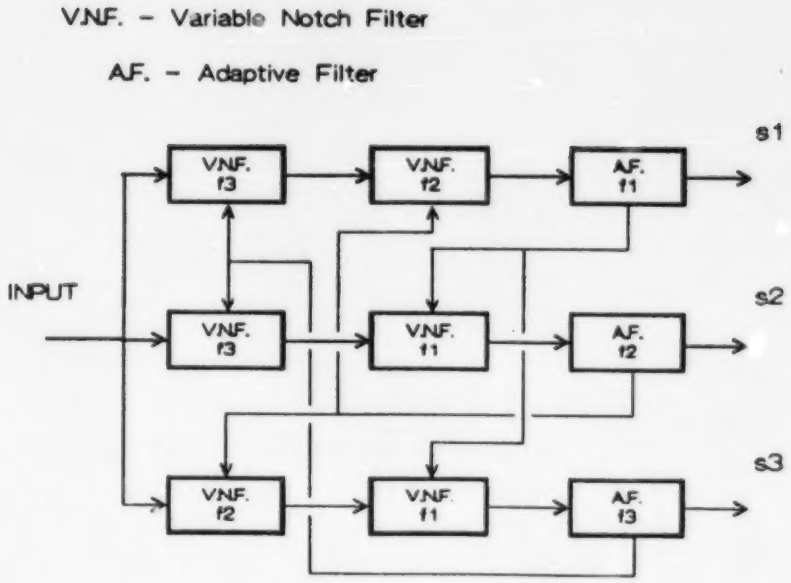

Fig. 1 Decomposition of a signal into its three components s1,s2 and s3. Each adaptive filter controls the notch filters on the other two channels.

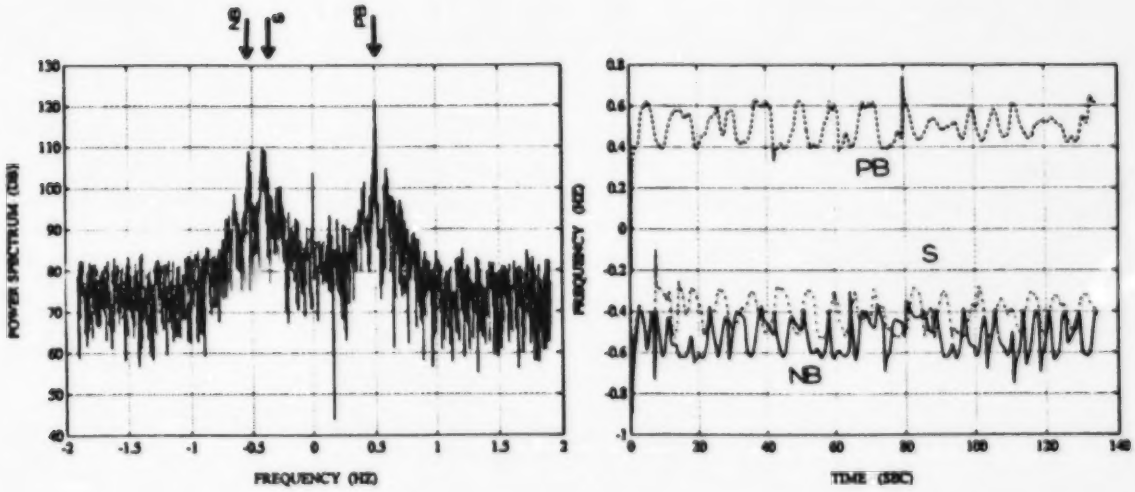

Fig. 2 a) Power spectrum of HF radar data with a ship signal and ocean clutter. b) Frequency variations of the three components estimated using the scheme of Fig. 1. (PB - positive Bragg, NB - negative Bragg, S - ship)